Sun-spots and Magnetic Disturbance. By William Ellis, F.R.S.

The paper by Father Sidgreaves, appearing in vol. 54 of the *Memoirs of the Royal Astronomical Society*, "On the Connexion between Solar Spots and Earth-magnetic Storms," takes up a difficult subject. The general correspondence between the rise and fall of solar spots and terrestrial magnetism, whether measured by the variation of magnetic diurnal range or by the number of days of magnetic disturbance and storm, has been sufficiently well shown; but as regards correspondence in individual particulars, little that is really satisfactory has been so far evolved. The Rev. A. L. Cortie (*Monthly Notices* for 1900 May), in treating of the duration of Sun-spots, has shown that numerous groups are seen through several successive rotations of the Sun, but the author of the paper first mentioned has carried the matter further, by undertaking a considerable discussion of the question of the extent to which relation between individual solar spots and terrestrial magnetic disturbances and storms may be traced. Any serious consideration of this question deserves attention, since such work usually involves much labour. The general effect observable by those who have studied the matter is that, in our latitude, there may be at one time a large solar spot with great magnetic disturbance accompanied by remarkable aurora (as in 1882 November and in 1898 September), when Sun, Earth, and Earth's atmosphere are all involved; at another time a considerable solar spot may appear without accompaniment of unusual magnetic movement; and again magnetic disturbance may occur without any noteworthy spot.

Lord Kelvin, in his presidential address to the Royal Society in 1892, estimating the amount of work which must be done at the Sun to produce a terrestrial magnetic storm, considered the result obtained as absolutely conclusive against the supposition that terrestrial magnetic storms are due to magnetic or other action of the Sun, adding that it seems as if we may be forced to conclude that the supposed connection between magnetic storms and Sun spots is unreal, and the seeming agreement between the periods a mere coincidence. But to show that the Sun does not directly produce magnetic disturbance was not to prove that no relation existed, or that the agreement between the periods was accidental. The fact of general relation, however it is to be explained, is so far evident that theory must take account of it (*Proc. Royal Society*, vol. lxiii. p. 64). Lord Kelvin, in demonstrating the improbability of the existence of direct connection, may be understood to have had more in mind such a circumstance as the simultaneous observation by Carrington and Hodgson of an outburst on the Sun on 1859 September 1, corresponding in time with a magnetic movement shown on the photographic magnetic records, to which indeed he had referred in an earlier

portion of his address. Carrington, one of the observers of the solar movement, while considering the phenomena as deserving of notice, said that "he would not have it supposed that he even leans towards hastily connecting them." An occurrence so striking attracted attention, but unfortunately the narrative became repeated with exaggeration of statement, inducing a belief in direct connection. But time at last showed that here was apparently misconception, for although the Sun, in the ordinary routine of solar work, has since been unremittingly watched, and a continuous photographic magnetic record also maintained, similar conditions have not been again observed. The magnetic motion, in the case in question, was in itself in no way remarkable, was indeed slight, and of a character and magnitude such as often occurs, and much greater movements are also sufficiently numerous, but yet direct correspondence has not been made out. The apparent connection, thus having in after years received no further confirmation from observation, was shown also by Lord Kelvin thirty-three years afterwards to be from other considerations improbable. But, as before said, the general relation, both with variation of diurnal range and with frequency of magnetic disturbance and storm, is undoubted.

A later sentence in the same address runs: "We have at present two good and sure connections between magnetic storms and other phenomena : the aurora above, and the earth currents below, are certainly in full working sympathy with magnetic storms." The observation of earth currents at Greenwich Observatory, continued through many years, entirely supports this statement. When the ordinary diurnal magnetic variation is alone present, whether at maximum or minimum of Sun spots, earth currents are extremely feeble ; but the appearance of magnetic disturbance, superposed on the ordinary diurnal movement, brings up at once a corresponding active earth current, and in very pronounced cases there may be also aurora. The magnetic irregularity and the active earth current are twin manifestations of an energy in the sense that one is never present without the other. Even a small superposed magnetic movement occurring suddenly is at once accompanied by a brisk little earth current. The correspondence is complete, the earth current being ever present with magnetic irregularity or storm. The same condition is found to exist at other places.

Thus in our latitude we may have (1) a large Sun-spot accompanied by magnetic disturbance + earth current, and, it may be, aurora—that is, the disturbing element involves both Sun and Earth ; or (2) a considerable Sun-spot may appear with magnetic quiet ; or (3) magnetic disturbance + earth current with solar quiet. In case 2 the Sun only is involved, and in case 3 the Earth only. Father Sidgreaves appears now to make out that the greater the Sun-spot the more frequently relatively is there accompaniment of magnetic disturbance or storm ; not that there is direct correspondence, but that during a certain period there is

disturbance over a large field, influencing both Sun and Earth, the Sun-spot, or whatever produces it, being usually a determining element, not in all cases apparently, since a considerable spot may appear without magnetic storm ; and magnetic disturbance may arise with solar quiet—that is, the area of disturbance may be variable. Whatever may be the cause that extends or restricts the area, we obtain a knowledge of its extent unfortunately only by the Sun-spot on the one side, and by the magnetic disturbance and its accompaniments on the other side—phenomena both of which may be in part or degree of the nature of secondary effects.

Another circumstance deserves notice. Many magnetic storms commence with a very sharp movement of lesser or greater magnitude occurring simultaneously in all elements, declination, horizontal force, and vertical force, with accompanying earth current. This first movement may somewhat precede the magnetic disturbance or storm, or it may itself usher in the storm. In either case the distinctive characteristic is that the initial movement is sudden, sometimes sudden and large, and in the majority of cases at Greenwich is in the same direction, increasing the magnetic declination, horizontal force, and vertical force. And any marked or considerable initial movement becomes felt at the same absolute time—not nearly at the same time, but absolutely so, as nearly as the scale employed for photographic registration will allow of measurement—at places widely distributed over the earth's surface, each place having, as at Greenwich, its own distinctive characteristic as regards variation of the different magnetic elements. Magnetic disturbance having once set in, the following movements show similarity at places not far apart, but considerable dissimilarity at places widely separated ; the first impulse however coming commonly after some period of magnetic quiet is found, as described, to be in a special degree simultaneous at different places. The Earth as a whole seems to feel an instantaneous shock, which would thus appear to be by action from without. (*Proc. Royal Society*, vol. 52, p. 191.)

As to the fluctuations that occur in magnetic storms, Sir George Airy, in a paper "First Analysis of 177 Magnetic Storms," communicated to the Royal Society in 1863, suggested that there may be something in proximity to the earth which he would call a magnetic ether, in which currents exist liable to interruptions or perversions that produce violent eddies and whirls, instancing the cyclonic and other phenomena of atmospheric storms and whirlpools in water ; and Dr. Schmidt (*Terrestrial Magnetism*, vol. 5, p. 87), considering the diurnal magnetic variation to be referable to electric currents in the upper regions of the atmosphere, believes that the immediate cause of magnetic storms is to be referred to electric whirls or vortices which separate themselves from the general electric field in the atmosphere just as do the cyclones and anti-cyclones known to meteorologists, and he is led to conclude that for the greater part the

causes of our observed magnetic storms come from outside the earth's crust.

There is yet a phase of magnetic disturbance about which something may be said. Active magnetic disturbance and magnetic storms cluster principally, as we know, about periods of Sun-spot maximum, those about Sun-spot minimum being characterised by more or less prolonged magnetic quiet. But considering magnetic disturbance with reference to the year, it is found that at Greenwich there is also a seasonal variation. The number of days of magnetic disturbance during the period 1848 to 1897, classed in my paper (*Monthly Notices* for 1900 December) as being days of active and great disturbance, is 374, and their seasonal distribution, taking February, March, and April to represent spring, and May, June and July to represent summer, and so on, is as follows :—

Number of Days of Active and Great Magnetic Disturbances at Greenwich, 1848 *to* 1897.

Spring.	Summer.	Autumn.	Winter.
121	66	115	72

Near equinoxes 236.
Near solstices 138.

There is a certain irregularity in individual years, noteworthy disturbance appearing sometimes unusually early in the year, as in 1861 January, and sometimes unusually late, as in 1882 November; but in the aggregate of years it is seen that a distinct seasonal variation exists. A closer examination shows that the spring maximum appears, on the whole, to fall somewhat before the equinox, and the autumn maximum somewhat after the equinox, in the months of February and October respectively. Thus we have, superposed on the variation of magnetic disturbance with Sun-spot frequency, a seasonal variation with maxima at the equinoxes and minima at the solstices, showing that the earth or its near surroundings has a part in determining the form in which the external influence reaches us. The related physical circumstance is that at the equinoxes, when disturbance is more frequent, the whole surface of the earth comes under the influence of the sun, whilst at the solstices, when magnetic disturbance is less frequent, a portion of the surface remains for a considerable period in shadow.

Attention may be drawn also to the relation existing between magnetic disturbance and the aurora. In our latitude not only do both phenomena vary with Sun-spot frequency, but the aurora is at Greenwich subject to a like seasonal variation. Extracting from Mr. R. C. Mossman's paper on "The Aurora Borealis in London from 1707 to 1895" (*Journal of the Scottish Meteorological Society* for 1897), the number of days of aurora during the years

1848 to 1895, and combining the months as for magnetic disturbance, we find :—

Number of Days of Aurora in London, 1848 *to* 1895.

Spring.	Summer.	Autumn.	Winter.
57	14	63	43

Near equinoxes 120.
Near solstices 57.

Here is a seasonal variation similar to that in number of days of magnetic disturbance, and here also the spring and autumn maxima occur in the months of February and October respectively. In higher latitudes the seasonal variation of the aurora is different, showing the local terrestrial effect to be different at different places on the Earth's surface ; is it also different in the case of number of days of magnetic disturbance ?

Observations of the Sun during 1901 *May* 17, 18, *and* 20, *at Mells, near Frome,* 10 *miles due south of Bath.* By Maures Horner.

On several occasions I have tried to examine the edge of the solar surface before and after a total eclipse in order to ascertain whether the prominences and metallic eruptions, which are seen by means of the spectroscope at other times compare in size and shape with the phenomena of a total eclipse.

In May last there was an opportunity of observing the Sun while the total eclipse was actually in progress, but owing to the screen of east wind haze—so persistent all through the spring—it was impossible to get satisfactory results, although the sky was remarkably free from cirrus and cumulus. On Friday, the 17th, I sketched the contour fairly accurately, using on the 5-inch Cooke one prism of very dense Iena glass by Hilger, which gives almost perfect definition, and widely separates the sodium lines with a low power. The drawing shows little solar activity, the E.N.E. limb alone displaying a certain amount of disturbance, probably due to the collection of small spots which came into view on the 19th. Further south, on the same side, was a fairly large prominence, with the peculiarity of a curious patch of bright colour between the two points. The same elevated bright cloud appearance was also visible in the south-west quadrant west of two rather dim forms at about 200°, which were quite conspicuous whenever the haze became a little more transparent. On the north-west limb there was a long attenuated form and a bright spot at the exact west point. With these exceptions the Sun's limb was practically undisturbed.

The haze was bad enough at noon on Friday, and therefore at 5.30 on Saturday morning there was not much probability of any